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DE-A- 2 003 227  
DE-A- 2 646 798  
FR-A- 1 017 822  
GB-A- 2 029 271  
US-A- 4 135 667

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## Description

This invention relates to powder charging for example for electrostatic powder painting.

It is known from DE-A-2646798 to provide an insulative tubular passage with a pair of needle electrodes connected to high potential sources of opposite polarity and thus create a field therebetween through which the powder flows carried by a conveying gas.

Further prior art is shown in Figures 17 and 18 of the drawings accompanying this specification, in which the field is generated between the corona discharge needle electrode 43 and the cylindrical electrode 44. Additional gas is blown into the passage with the object of reducing or minimising powder build-up on the electrodes.

The problems with the prior art are that powder may be caused to adhere to one of the electrodes even despite the cleaning gas, and this causes generation of back corona discharge, an opposite polarity ionic current and effectively neutralization of the desired charging of the power particles. Further problems are due to gravitational effects on the powder which tend to cause it to flow non-uniformly in relation to the cross section of the passage, and the non-uniformity of the current density in relation thereto.

The object of the invention is to solve these problems and provide improvements.

According to the invention there is provided a powder charging apparatus which comprises an insulative tubular passage, means for delivering to the tubular passage a conveying gas and the powder to be charged, a pair of plasma electrodes for respectively generating plasma of required polarity and plasma of opposite polarity, means for applying DC voltage to said plasma electrodes, said plasma electrodes being connected so that the field therebetween extends in said tubular passage and the apparatus being arranged so that the said powder flows in a dispersed state in said gas through an area of said field where mainly ions of required polarity exist, one of said pair of plasma electrodes being a plasma electrode of required polarity and the other being a plasma electrode of opposite polarity, and is characterised in that the location of the other of the electrodes relative to the powder flow is such that it is substantially avoided that the powder in the dispersed state flows through the area of the field where mainly ions of said opposite polarity exist, and said DC voltage is intermittently applied via a gap which disperses ions well in said insulative tubular passage

Also according to the invention there is provided an electrostatic powder painting apparatus which comprises a powder charging apparatus in-

cluding an insulative tubular passage, means for delivering to the tubular passage a conveying gas and the powder to be charged, a pair of plasma electrodes for respectively generating plasma of required polarity and plasma of opposite polarity, means for applying DC voltage to said plasma electrodes, said plasma electrodes being connected so that the field therebetween extends in said tubular passage and the apparatus being arranged so that the said powder flows in a dispersed state in said gas through an area of said field where mainly ions of required polarity exist, one of said plasma electrodes being a plasma electrode of required polarity and the other being a plasma electrode of opposite polarity, and is characterised in that the location of said other electrode relative to the powder flow is such that it is substantially avoided that the powder in the dispersed state flows through the area of the field where mainly ions of said opposite polarity exist, and said DC voltage is intermittently applied via a gap which disperses ions well in said insulative tubular passage

The invention also provides a powder charging method including the steps of providing an insulative tubular passage, with one plasma electrode on an axis therein for generating plasma of required polarity and another plasma electrode therein for generating plasma of opposite polarity, delivering a conveying gas and powder to be charged to the passage, applying D.C. voltage to said electrodes to create a field therebetween extending in said tubular passage so that the powder flows in a dispersed state through an area of said field where mainly ions of required polarity exist, and characterised in that the location of said other electrode relative to the powder flow is such that it is substantially avoided that the powder in the dispersed state flows through the area of the field where mainly ions of said opposite polarity exist, and in that said D.C. voltage is applied intermittently between said electrodes to generate plasma in said passage in the direction of said axis and the powder is transported in said passage in the direction of said axis

Finally the invention provides a powder charging method including the steps of delivering a conveying gas and the powder to a tubular insulative passage with a pair of plasma generating electrodes therein, for respectively generating plasma of required polarity and plasma of opposite polarity and applying D.C. voltage intermittently to said plasma electrodes which are so connected that the field therebetween extends in said tubular passage and so that the powder flows in said gas through an area of the field where mainly ions of required polarity exist and characterised in that the location of the electrode for generating plasma of

opposite polarity relative to the powder flow is such that it is substantially avoided that the powder in the dispersed state flows through the area of the field where mainly ions of said opposite polarity exist, and in that said powder is caused to flow only through the area where the mainly desired polarity ions exist

#### BRIEF DESCRIPTION OF THE DRAWINGS:

Fig. 1 is a longitudinal cross-section view of a powder charging apparatus according to the present invention;

Fig. 2 is a cross-section view taken along line II-II in Fig. 1 as viewed in the direction of arrows;

Figs. 3, 4, 5 and 6, respectively, are longitudinal cross-section views of other preferred embodiments of the present invention;

Fig. 7 is a cross-section view taken along line VII-VII in Fig. 6 as viewed in the direction of arrows;

Figs. 8, 9, 10, 11 and 12, respectively, are longitudinal cross-section views of still other preferred embodiments of the present invention;

Figs. 13, 14, 15 and 16, respectively, are longitudinal cross-section views of different preferred embodiments of an electrostatic powder painting apparatus according to the present invention; and

Figs. 17 and 18, respectively, are longitudinal cross-section views of two different examples of the powder charging apparatuses in the prior art.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS:

In the preferred embodiment of the present invention illustrated in Figs. 1 and 2, a desired polarity plasma electrode 3 is a needle electrode having a small radius of curvature at its tip end and forms a low voltage side plasma electrode, whereas an opposite polarity plasma electrode 4 is a needle electrode having a large radius of curvature at its tip end and forms a high voltage side plasma electrode, and between these two electrodes is intermittently applied a high voltage of 20,000 - 80,000 volts from a D.C. voltage source 5 through a discharge gap 5b. As a result, between the respective electrodes is intermittently generated bipolar corona discharge as shown in Fig. 1, and at the tip ends of the respective electrodes is respectively formed plasma. In this instance, since the radius of curvature at the tip end of the desired polarity plasma electrode 3 is small, a desired polarity ionic current 6 drawn from this electrode is large as compared to an opposite polarity ionic current 7 drawn from the opposite polarity plasma electrode 4, and also is present over a long broad

region. Accordingly, powder carried by gas indicated by an arrow 8 is stirred by a choke 10 and a dispersing gas 11a ejected from a dispersing gas jet 11 provided at this choke and becomes well dispersed powder 12, and then it is charged while passing through a space 13 where mainly desired polarity ions exist and becomes charged powder 9.

In this case, as will be apparent from Fig. 1, since a space 14 where mainly opposite polarity ions exist is substantially separated from the tubular passage 2 by means 14 for bringing the powder remote from this space, it scarcely occurs that the electric charge produced by the desired polarity ionic current is neutralized by the opposite polarity ionic current 7, and furthermore, this is further assured by an adhesion preventing gas 19 fed through an opposite polarity plasma electrode gas jet port 18 around the opposite polarity plasma electrode. In the powder charging apparatus according to the present invention, since the used electrodes are both corona discharge electrodes having plasma formed at their tip ends, owing to the effects of ionic currents, electric winds, D.C. repulsions, etc. issued from the electrodes by the actions of the plasmas and the electric fields generated at the tip ends of the respective corona discharge electrodes, the plasma electrodes have the effects of charging the particles existing in the proximity of the electrode and ejecting them, so that powder particles would not adhere to and accumulate on the electrodes during operation, performances of the electrodes would not change and operation can be continued stably for a long period of time. It is to be noted that around the desired polarity plasma electrode 3 is also provided a desired polarity plasma electrode gas jet port 16 in a ring shape, and through this gas jet 16 an adhesion preventing gas 17 is blown in at a high velocity. The adhesion preventing gases 17 and 19 are for the purpose of preventing adhesion of powder to the tip ends of the electrodes under a transient condition mainly upon starting and stopping of operation of a torch.

Since an output terminal 5a of the D.C. voltage source 5 and the opposite polarity plasma electrode 4 are connected via a discharge gap 5b, the opposite polarity electrode 4 is fed with a voltage from the D.C. voltage source 5 via the discharge gap 5b, and while the voltage is increasing as the feeding time elapses, when the voltage has become a high voltage, between that electrode 4 and the desired polarity plasma electrode 3 are momentarily generated the opposite polarity ionic current 7 and the desired polarity ionic current 6, hence the voltage of the opposite polarity plasma electrode 4 is lowered abruptly, and the above-mentioned respective ionic currents 6 and 7 would cease.

If the currents cease, the voltage of the opposite polarity plasma electrode 4 is again raised by the voltage of the D.C. voltage source 5 fed through the discharge gap 5b, and the above-described operation is repeated. The repetition is effected normally at a frequency of 5KC - 50KC.

In this way, the respective ionic currents 13 and 14 flow intermittently, and by varying the relative velocity between the ion particles and the powder particles at that time, a charging rate can be enhanced.

It is to be noted that if a powder charging apparatus according to the present invention of the type shown in Fig. 1 and having a large capacity is necessitated, the object can be achieved by providing the electrode pair in multiple along the direction of flow in the tubular passage.

In another preferred embodiment shown in Fig. 3, on the inside of a cylindrical body 1 made of insulating material whose cross-section configuration is circular, is formed a tubular passage 2 for transporting powder 8 carried by gas, on the axis of this tubular passage 2 is disposed a thin corona discharge electrode so as to operate as a desired polarity plasma electrode 3, and a thick corona discharge electrode opposed to that plasma electrode 3 is provided on an outer peripheral surface of the tubular passage 2 so as to operate as an opposite polarity plasma electrode 4. In this instance, the inner surface of the tubular passage 2 where the opposite polarity plasma electrode 4 is disposed forms a surface converging towards the upstream which is contiguous to a choke 10 at the upstream, also at the downstream of that inner surface, a dispersing gas indicated by an arrow 11a is ejected from a ring-shaped dispersing gas jet port 11 to keep the tip end of the opposite polarity plasma electrode 4 always clean, hence well dispersed powder 12 is produced by the effect that the dispersing gas traverses the tubular passage 2 to stir and disperse the powder and is blown towards a space 13 where mainly a desired polarity ionic current 6 drawn from the tip end of the desired polarity plasma electrode 3 exists, and thereby the powder can be charged. In this case, since the opposite polarity ionic current 7 drawn from the opposite polarity plasma electrode 4 is in itself small because of the large radius of curvature at the tip end of the electrode 4 and the construction is such that the powder may be brought remote from the space 7 where mainly the opposite polarity ions exist due to the choke 10, neutralization of the charge of the desired polarity by the opposite polarity ions can be suppressed small, and after all, a charging efficiency can be made high as a whole. In this embodiment, reference numeral 5 designates a D.C. voltage source for applying D.C. voltages to the respective electrodes,

one end of a lead wire 5c is connected to an output terminal 5d of the D.C. voltage source 5, and the other end thereof is opposed to the desired polarity plasma electrode 3 via a discharge gap 5b of 1 - 5 mm. Reference numeral 5a designates a high frequency voltage source for supplying electric power to that electrode. It is to be noted that the desired polarity plasma electrode 3 operates as a high voltage side plasma electrode and is disposed within a protective tube 3a, and an adhesion preventing gas 17 ejected at a high velocity from a high voltage side plasma electrode gas jet port 16a at the tip end of the protective tube 3a, serves to prevent discharge products produced in the discharge gap 5b and the powder from adhering to the tip end of the desired polarity plasma discharge electrode 3, which would occur mainly under a transient condition upon starting or stopping.

Fig. 4 shows another preferred embodiment, in which a desired polarity plasma electrode 3 is provided on an inner surface of a tubular passage 2 formed by a cylindrical body 1. In this embodiment, powder 8 carried by gas is introduced from a tangential direction of the tubular passage 2 to the upstream side of the desired polarity plasma electrode 3 by means of a powder introducing tubular passage 1a, and an adhesion preventing gas 19 is supplied through an opposite polarity plasma electrode gas jet port 18 formed around an opposite polarity plasma electrode 4. Thus, by a D.C. high voltage applied intermittently between the grounded opposite polarity plasma electrode 4 and the desired polarity plasma electrode 3 from a voltage source 5 via a discharge gap 5b, corona discharge is generated intermittently between the respective electrodes, and as shown in Fig. 3, a desired polarity ionic current 6 drawn from the desired polarity plasma electrode 3 forms a space 13 along the tube wall where mainly desired polarity ions exist. In this case, the powder introduced into the tubular passage 2 through a powder introducing side port 24 would turn round at a high velocity in the tubular passage 2 and would become well dispersed powder 12 along the tube wall, then it flows out as traversing the space 13 where mainly the desired polarity ions exist, and therefore, well charged powder 9 can be obtained. In this case, since the powder 8 would not enter the space 14 where mainly an opposite polarity ionic current 7 exists as assisted by the action of the adhesion preventing gas 19, neutralization by the opposite polarity ionic current 7 of the charge given by the desired polarity ionic current 6 can be suppressed to a very small amount. In this embodiment, while an adhesion preventing gas could be blown towards the desired polarity plasma electrode 3 if necessary, in many cases the powder can be prevented from adhering to the desired polarity plasma electrode 3

by a strong turning flow itself with the illustrated construction.

Fig. 5 shows still another preferred embodiment of the present invention, in which on the inside of a cylindrical body 1 whose cross-section configuration is circular, is formed a tubular passage 2 for transporting powder 8 carried by gas, a desired polarity plasma electrode 3 consisting of a needle electrode having a small radius of curvature at its tip end is disposed on the axis of the tubular passage 2, also an opposite polarity plasma electrode 4 having a large radius of curvature at its tip end is disposed on the same axis as opposed to the desired polarity plasma electrode 3, and between these two plasma electrodes is intermittently applied a D.C. high voltage from a high frequency voltage source 5a through a multi-stage voltage step-up circuit 5 and a discharge gap 5b. In addition, at a location a little shifted from the middle of the respective electrodes towards the upstream side is provided a ring-shaped dispersing gas jet port 11, and a dispersing gas 11a is blown into the tubular passage 2 through this jet port. Normally, in a powder charging apparatus of the class required for electrostatic powder painting or the like, in many cases transportation of powder through a tubular passage is not effected at so high velocity, and in such cases the powder carried by gas form a deviated flow as shown at 25, hence even if the powder flow should pass through a space 14 where mainly opposite polarity ions exist which space is formed in the proximity of the tip end of the opposite polarity plasma electrode 4, in most cases the powder would not be charged so much in substance. Accordingly, by making a dispersing gas 11a spout strongly from a dispersing gas jet port 11 just behind this space 14 and making well dispersed powder 12 pass through a space 13 where mainly desired polarity ions exist, charging by only the desired polarity ions can be practiced while substantially avoiding neutralization by the opposite polarity ions, and thereby charged powder 9 can be obtained stably for a long period of time. Although positive means for bringing powder remote from the space where the opposite polarity ions exist is provided in other preferred embodiments (Figs. 1, 4, 6 and 8) of the present invention, the embodiment shown in Fig. 5 can be deemed to include means for bringing powder remote from a space where opposite polarity ions exist according to the present invention in certain means, as will be seen from the above description.

In yet another preferred embodiment of the present invention shown in Figs. 6 and 7, on the inside of a cylindrical body 1 having a circular cross-section configuration and made of insulating material is formed a tubular passage 2 for transporting powder 8 carried by gas, along the axis on

the upstream side of the inner surface of that tubular passage 2 is disposed on opposite polarity plasma electrode 4 consisting of a needle electrode having a large radius of curvature at its tip end, conical means 15 for bringing the powder remote from the electrode 4 is disposed just upstream of the electrode 4, and a desired polarity plasma electrode assembly 3a is disposed as opposed to the conical means 15. The desired polarity plasma electrode assembly 3a in this preferred embodiment is composed of two electrodes 3a-1 and 3a-2 disposed close to each other, which are applied with high voltages of different magnitudes from different positions of a D.C. voltage source 5 contained in the cylindrical body 1 through a protective resistor 3a-1R and a discharge gap 5b-1, and a protective resistor 3a-2R and a discharge gap 5b-2, respectively, hence plasma induced by minute spark discharge is formed between the respective electrodes 3a-1 and 3a-2, and thereby a desired magnitude ionic current of sufficient magnitude is drawn intermittently towards the opposite polarity plasma electrode 4, so that a space 13 where mainly desired polarity ions exist can be formed. It is to be noted that reference numeral 5a designates a high frequency voltage source for supplying electric power to the D.C. voltage source. In the middle between these desired polarity plasma electrode and opposite polarity plasma electrode are formed a plurality of turning flow jet ports 11 opening in the tubular passage 2, a dispersing gas 11a is fed through these jet ports 11, and after the powder 8 existing within the tubular passage 2 has been well stirred and dispersed by the dispersing gas 11a, the powder comes close to the tube wall and passes through the space 13 where mainly the desired polarity ions exist, and monopolarly charged powder 9 can be obtained. In this embodiment, owing to the actions of both the means 15 for bringing the powder 8 remote from the opposite polarity plasma electrode 4 and the turning flow jet port 11 which serves as a dispersing gas jet port, the powder would scarcely come close to a space 14 where mainly opposite polarity ions exist, so that neutralization of charge caused by the opposite polarity ions can be substantially avoided, and thereby stable charging of powder can be practiced at a high efficiency for a long period of time. It is to be noted that either one of the above-described discharge gaps 5b-1 and 5b-2 can be omitted without any inconvenience.

In a further preferred embodiment shown in Fig. 8, on the inside of a cylindrical body 1 made of insulating material and having a circular cross-section configuration is formed a tubular passage 2 for transporting powder 8 carried by gas, a desired polarity plasma electrode consisting of a needle electrode having a small radius of curvature at its

tip end is disposed on the outlet side of the axis of the tubular passage 2, a high voltage fed from a D.C. voltage source 5 is intermittently applied to this plasma electrode 3 through a discharge gap 5b, an adhesion preventing gas 17 is ejected from a desired polarity plasma electrode gas jet port 16 formed around the plasma electrode 3, an opposite polarity plasma electrode 4 consisting of a needle electrode 4 having a large radius of curvature at its tip end is disposed as opposed to the plasma electrode 3, around the plasma electrode 4 is disposed a hollow conical body 15 serving as means for bringing powder remote from the opposite polarity plasma electrode 4, and arrangement is done such that an adhesion preventing gas 19 may be blown from the periphery of the opposite polarity plasma electrode 4 through an opposite polarity plasma electrode gas jet port 18.

In this preferred embodiment, since the powder would pass through the region around the opposite polarity plasma electrode 4 without entering a space 14 where mainly opposite polarity ions exist, and since thereafter the powder is introduced into a space 13 where mainly desired polarity ion exist while being gathered to the central region of the tubular passage 2 under the condition where the powder has been well dispersed by a dispersing gas 11a ejected from a ring-shaped gas jet port 11, charging of powder can be practiced at a high efficiency, substantially without neutralization of charge caused by the opposite polarity plasma electrode 4, and well charged powder 9 can be obtained.

In the powder charging apparatus according to the present invention, generally a high efficiency can be easily obtained if a voltage-current characteristic of a desired polarity plasma electrode is chosen larger than a voltage-current characteristic of an opposite polarity plasma electrode. However, in the case where means for bringing powder remote from a space 14, in which mainly opposite polarity ions exist, is provided as in the case with Figs. 1, 3, 4, 5, 6 and 8, in some cases it is not always necessary to make the voltage-current characteristics of the respective plasma electrodes different.

Fig. 9 shows a still further preferred embodiment of the present invention, in which charging of powder is practiced relying upon a principal effect of the fact that a large difference is maintained between voltage-current characteristics in an operating state of a desired polarity plasma electrode 3 and an opposite polarity plasma electrode 4 according to the present invention. In Fig. 9, on the inside of a cylindrical body 1 made of insulating material and having a circular cross-section configuration is formed a tubular passage 2 for transporting powder 8 carried by gas, a desired polarity

plasma electrode 3 having an extremely small radius of curvature at its tip end and having good durability is disposed on the axis of the tubular passage 2, an opposite polarity plasma electrode 4 having a large radius of curvature at its tip end is disposed as opposed to the former plasma electrode 3 and is grounded, also a high voltage is intermittently applied to the desired polarity plasma electrode 3 from a D.C. voltage source 5 via a discharge gap 5b, further a dispersing gas 11a is ejected from a ring-shaped dispersing gas jet port 11 provided in the region of a choke 10 formed at the upstream of the opposite polarity plasma electrode 4 to feed the powder to the plasma electrodes in a well dispersed condition, and then the powder is made to pass through the desired polarity plasma electrode region, it is to be noted that reference numeral 5a designates a high frequency voltage source for feeding electric power to the D.C. high voltage circuit 5. With the above-mentioned provision, the powder carried by gas is already in a well dispersed state and is liable to be charged, and since it passes, at first, through a space 14 where mainly opposite polarity ions exist that is formed downstream of the opposite polarity plasma electrode 4, it is once charged in the opposite polarity, but as it subsequently passes through a space 13 where a strong desired polarity ionic current drawn from the desired polarity plasma electrode 3 having a sufficiently large voltage-current characteristic exists, the previously given charge is offset here, and after the powder has been charged sufficiently in the desired polarity it is ejected as shown by an arrow 9. In order to achieve such object, it is necessary to give a large difference between the charging characteristics of the respective electrodes, and although in some cases selection of a flow rate and polarity of the powder to be processed may be limited, the structure is extremely simple, and depending upon use, the illustrated structure can well achieve the object of the present invention.

It is to be noted that even if the means 10, 11 for dispersing gas as employed in the above-described embodiment is not especially provided, in the event that powder can be supplied to the region where the electrodes exist already in a well dispersed state depending upon characteristics, a feed rate and a flow velocity of the carrier gas, in some cases these powder dispersing means are unnecessary to be especially provided. The embodiment in such cases is also included in the scope of the present invention.

In a yet further preferred embodiment shown in Fig. 10, on the inside of a cylindrical body 1 having a circular cross-section configuration is formed a tubular passage 2 for transporting powder 8 carried by gas, on the inner surface of the tubular passage

2 is disposed a desired polarity plasma electrode 3 having an extremely small radius of curvature at its tip end, an opposite polarity plasma electrode 4 having a large radius of curvature at its tip end is disposed as opposed to the former plasma electrode 3, and a D.C. voltage difference is intermittently applied between these plasma electrode from a D.C. voltage source 5 via a discharge gap 5b. In this case, like the other embodiments it is not always necessary to ground one of the electrodes, but the case where a potential difference is maintained between the respective electrodes while applying two different voltages from ungrounded terminals of the voltage source 5 to the respective electrodes just as this embodiment, is also included in the scope of the present invention.

In addition, in this preferred embodiment, a dispersing gas jet port 11 for blowing in a dispersing gas 11a in a tangential direction is provided on the inner surface of the tubular passage 2, thereby the gas can be well dispersed under the condition where it has approached to the tube wall, then at first the gas passes through a space 14 where mainly opposite polarity ions exist which space is formed in the proximity of the opposite polarity plasma electrode 4, and thereafter it passes through a space 13 where mainly desired polarity ions exist. However, in this instance there is a large difference in the radius of curvature at the tip end of the corona electrode, hence the space 13 where mainly the desired polarity ions exist is far greater and stronger than the space 14 where mainly the opposite polarity ions exist, and therefore, the powder can be sufficiently charged with the desired polarity as a whole, and is ejected from the apparatus as charged powder 9.

In this embodiment also, like the embodiment shown in Fig. 9, in the event that the powder comes into the tubular passage 2 in a already well dispersed state, in some case the dispersing means 11 and the dispersing gas 11a for the powder are not always necessary, but such case is also included in the scope of the present invention.

Fig. 11 shows a still further preferred embodiment of the present invention which is especially suitable for practicing a high-efficiency large-capacity powder charging apparatus in that a plasma generating capability of the desired polarity plasma electrode is chosen especially large.

In Fig. 11, on the inside of a cylindrical body 1 made of insulating material and having a circular cross-section configuration is formed a tubular passage 2 for transporting powder 8 carried by gas, and on the axis of that tubular passage 2 is disposed an A.C. drive type plasma generating electrode which operates as a desired polarity plasma electrode 3. In this desired polarity plasma electrode 3, at the center of a thin tubular insulator 3Y

made of ceramics or the like is disposed a central electrodes 3Z, on the outside of them is disposed a surface electrode 3X in a head-band shape, between these central electrode 3Z and the surface electrode 3X is applied an A.C. high voltage from an A.C. voltage source 26 via a transformer 27, and furthermore to these electrodes is intermittently applied a D.C. voltage from a D.C. voltage source 5 through a discharge gap 5b.

An opposite polarity plasma electrode opposed to these electrodes could be normally a corona discharge electrode 4 having a large radius of curvature at its tip end, and if necessary, arrangement is such that an adhesion preventing gas 19 is ejected from an opposite polarity electrode gas jet port 18 provided around the opposite polarity plasma electrode 4 so that adhesion of powder to the tip end of the electrode 4 may be prevented, and this electrode 4 is grounded.

In addition, the apparatus is constructed in such manner that a dispersing gas 11a may be ejected from a ring-shaped dispersing gas jet port 11 opening between the respective electrodes and at this position the carried powder may take a sufficiently dispersed condition. The desired polarity plasma electrode used in this embodiment is favorable for realizing an especially strong and large-capacity powder charging apparatus according to the present invention, because extremely strong A.C. plasma is generated in the proximity of the surface electrode 3X by the A.C. high voltage applied between the surface electrode 3X and the central electrode 3Z and thereby the space 13 where mainly the desired polarity ions exist is strongly formed.

It is to be noted that in the case of the above-described desired polarity plasma electrode 3, since powder particles cannot approach to the proximity of this plasma electrode 3 due to an action of an extremely strong and uneven A.C. electric field formed in the proximity of the surface electrode 3X, in many cases there is no need to employ special adhesion preventing means, but for the purpose of preventing adhesion of powder upon starting and stopping an adhesion preventing gas could be introduced to the proximity of this electrode. In this figure, reference numerals not specifically referred to, are given to items which are common to other figures. In addition, the means for applying an A.C. voltage between the respective plasma exciting electrodes 3X and 3Z should not be limited to the system employing a transformer as illustrated in this embodiment, but a ripple voltage superposed on a D.C. voltage could be utilized by appropriately selecting a number of stages and circuit parameters in a high voltage generator circuit.

Fig. 12 shows a powder charging apparatus according to the present invention which is characterized in that on the inside of a cylindrical body 1 made of insulating material and having a circular cross-section configuration is formed a tubular passage 2 for transporting powder 8 carried by gas, an A.C. plasma generating electrode for intensely generating desired polarity ions is disposed in a ring shape on the inner surface of the tubular passage 2, and an opposite polarity plasma electrode 4 having a large radius of curvature at its tip end is disposed on the axis of the tubular passage 2 as opposed to the A.C. plasma generating electrode. In Fig. 12, on an inner surface of a ring 3Y normally made of ceramic insulator and provided on the inner surface of the tubular passage 2, is disposed a thin wire-shaped surface electrode 3X, also on the back side of the ring 3Y is disposed a broad planar ring-shaped electrode 3Z, these respective electrodes are supplied with A.C. power by an A.C. voltage 26 so that an A.C. high voltage may be applied between the respective electrodes via a transformer 27, and also a D.C. voltage source 5 for raising the potentials of the respective electrodes applied with the A.C. voltage as a whole is connected to these electrodes through a discharge gap 5b for switching on and off the voltage. In addition, the opposite polarity plasma electrode 4 is grounded through a lead wire 21, an adhesion preventing gas 19 is adapted to be ejected through an opposite polarity plasma electrode gas jet port 18 around the electrode 4, also a dispersing gas 11a is ejected through a dispersing gas jet port 11 from the middle between the respective electrode and thereby powder can pass through the tubular passage 2 in a well dispersed state as approaching to the inner wall of the tube. In this embodiment, since extremely intense A.C. plasma is formed in the periphery of the electrode 3X by the action of the high A.C. voltage applied between the electrode 3X and the electrode 3Z, an extremely large amount of desired polarity ions would flow without interruption towards the opposite polarity plasma electrode owing to an D.C. electric field established from these electrodes 3X and 3Z towards the opposite polarity plasma electrode 4 by the D.C. voltage source 5. Accordingly, the powder passing through the proximity of these electrodes as well dispersed and close to the tube wall can be ejected as very strongly charged powder 9, according to this system a preferred embodiment of the present invention which is extremely suitable in the event that it is desired to obtain powder having a high charge density in a large amount, can be established.

In the preferred embodiments of the present invention illustrated in Figs. 1 to 12 and described in detail above, as a desired polarity plasma lec-

trode mainly a corona discharge electrode having a small radius of curvature or an A.C. plasma generating electrode is employed, as an opposite polarity plasma electrode a corona discharge electrode consisting of a needle electrode having a relatively large radius of curvature is employed, and besides, as means for dispersing powder some embodiments employ a choke, some employ a dispersing gas and some employ a turning flow, or else a dispersing plate consisting of a baffle plate could be employed. In addition, as means for bringing powder remote from a space where mainly opposite polarity ions exist, some embodiments employ a space where the gas carrying the powder is not flowing, some employ a conical body, or else a diameter of a tubular passage is varied along the lengthwise direction of the tube, or as shown in Fig. 6 a baffle device is employed. However, it is possible to employ any arbitrary combination of these means so long as it does not depart from the essence of the present invention, and depending upon the objects of utilizations, they could be used as selected from the respective group and as combined together.

In addition, as means for preventing powder from adhering to and accumulating on the respective electrodes, a system in which gas is ejected so as to surround the electrodes, a system employing an A.C.-driven plasma generating electrode as shown in Figs. 11 and 12 as an electrode, or a system consisting of a combination of the above-mentioned systems, could be utilized as selected according to necessity.

In the following, description will be made on preferred embodiments in which the powder charging apparatus according to the present invention is utilized in an electrostatic powder painting apparatus, and in these preferred embodiments also, as described above, the basic constituent elements of the present invention such as electrodes, means for dispersing powder, means for bringing powder remote from a space where opposite polarity ions mainly exist, and the like could be employed as appropriately selected and combined according to an object of practice.

Fig. 13 shows one preferred embodiment in which an electrostatic powder painting apparatus having extremely excellent penetrating performance is formed by making use of the above-described powder charging apparatus according to the present invention. In this embodiment, on the inside of a cylindrical body 1 made of insulating material and having a circular cross-section configuration is formed a tubular passage 2 for transporting powder 8 carried by gas, a desired polarity plasma electrode 3 consisting of a needle electrode having a small radius of curvature at its tip end is disposed in the proximity of a terminal end



of the tubular passage 2, while an opposite polarity plasma electrode 4 consisting of a needle-like corona discharge electrode having a large radius of curvature at its tip end is disposed as opposed to the former plasma electrode 3, a high voltage is applied intermittently to the opposite polarity plasma electrode 4 from a D.C. voltage source 5 through a discharge gap 5b, and the above-described desired polarity plasma electrode 3 is grounded through a lead wire 20. Reference numeral 5a designates a high frequency voltage source for feeding electric power to the D.C. voltage source. At the upstream of the opposite polarity plasma electrode 4 is disposed, for example, a choke 10, if necessary, for the purpose of well dispersing the powder, thereby the powder passes at first through a space where mainly opposite polarity ions exist in a well dispersed state, thereafter it passes a space where mainly desired polarity ions exist, and it is ejected from the end of the tubular passage 2 as charged powder 9. In that instance, for the purpose of adjusting a pattern of ejection, a dispersing plate 28 is disposed, thereby appropriate divergence is given to the ejecting pattern, and in the case where the divergence caused by the dispersing plate is made small, provision is made such that a pattern adjusting gas indicated by an arrow 30 may be ejected from a pattern adjusting gas jet port 29 to adjust the pattern. In addition, reference numeral 31 designates an article to be painted. In the illustrated embodiment of the present invention constructed in the above-described manner, since the tip end of the electrostatic powder painting apparatus is held in a grounded condition by the lead wire 20, no electric field is formed between the apparatus and the article to be painted, hence when the powder 9 ejected from the tip end of the electrostatic powder painting apparatus is blown to the article to be painted, the so-called Faraday cage effect in which by the action of the electric field directed from the tip end of a gun to an article to be painted, powder is deposited in concentration to the portion subjected to a strong electric field and not deposited to a recessed portion as is the case with the conventional electrostatic powder painting apparatus, would not arise at all, but only in the event that the powder blown to the article to be painted has come close to the article to be painted, the powder is deposited to the article to be painted by a space charge electric field effect generated by electric charge possessed by the powder itself, and therefore, an electrostatic powder painting apparatus having an extremely excellent penetrating performance can be provided. In this connection, in the case where the powder is very strongly charged, and no voltage is applied to the tip end of the gun, sometime it occurs that the powder is dispersed

too much by mutual repulsion effects of the electric charge possessed by the powder itself and hence it becomes difficult to be blown into a narrow area, and in such instances, in some cases the lead wire 20 is connected to a terminal having an appropriate magnitude of D.C. potential in the voltage source 5 to form a weak electric field and thereby an electrostatic powder painting apparatus having an appropriate and high efficiency and an excellent penetrating performance is provided. Such embodiments are also included in the scope of the present invention.

In addition, it is quite similar to the previously described embodiments of the powder charging apparatus that in order to prevent the powder from adhering to the tip ends of the electrodes under a transient condition of starting or stopping, adhesion preventing gases 17 and 19 are used.

Fig. 14 shows another embodiment for providing an electrostatic powder painting apparatus that is very favorable in the case of practicing a thick-film electrostatic powder painting apparatus by making use of the powder charging apparatus according to the present invention. In this figure, on the inside of a cylindrical body 1 made of insulating material and having a circular cross-section configuration is formed a tubular passage 2 for transporting powder 8 carried by gas, a short tube 22 including an adjusting device 29 for adjusting a powder ejecting pattern is provided on the outlet side of the tubular passage 2 along its axis, a desired polarity plasma electrode 3 consisting of a corona discharge electrode having an extremely small radius of curvature at its tip end is disposed at the upstream of the short tube 22, an opposite polarity plasma electrode 4 having a relatively large radius of curvature at its tip end is disposed as opposed to the former plasma electrode 3 and is grounded, and a D.C. high voltage is intermittently applied to the desired polarity plasma electrode 3 from a D.C. voltage source via a discharge gap 5b. It is to be noted that while the discharge gap 5b is shown as located in the both end portions of a lead wire 5c in the drawings, this indicates merely possible mount positions of the discharge gap 5b, and it suffices to provide only in either one end portion. In addition, reference numeral 5a designates a high frequency voltage source for feeding electric power to the D.C. high voltage source 5. Furthermore, between the electrode 3 and the electrode 4 is provided means for dispersing powder by making use of a choke 10 which was already explained in detail above, and for the purpose of adjusting an ejecting pattern of charged powder 9, a flow rate of an ejecting pattern adjusting gas as indicated by an arrow 30 is adjusted. In addition, reference numeral 31 designates an article to be painted, and reference numeral 16 designates a jet port for ejecting

an adhesion preventing gas 17 which serves to prevent the powder from adhering to the tip end of the desired polarity plasma electrode. In the electrostatic powder painting apparatus according to the present invention constructed as described above, as already explained in detail, well dispersed powder can be sufficiently charged between the desired polarity plasma electrode and the opposite polarity plasma electrode, and it passes through the short tube 22 and is blown to the article to be painted. In this case, since the desired polarity plasma electrode applied with a high voltage is located in the proximity of the ejecting port, an intense electric field directed towards the article to be painted is formed thereby, hence powder charged by the action of this electric field travels towards the article to be painted and is deposited thereon, but in this instance since an electric current flowing from the desired polarity plasma electrode towards the article to be painted is sufficiently suppressed in substance due to existence of the short tube 22, on the surface of the article to be painted an ionic current flowing from the tip end of the electrostatic powder painting apparatus to the surface of the article to be painted is not present, hence back corona discharge would hardly occur, also since only an electric field exists, a painting efficiency can be held considerably high, and thereby electrostatic powder painting of an extremely thick film without accompanied by back corona discharge, can be practiced.

Fig. 15 shows still another embodiment for providing a very high performance electrostatic powder painting apparatus having a very high painting efficiency and an excellent back painting property by making use of the powder charging apparatus according to the present invention. In Fig. 15, on the inside of a cylindrical body made of insulating material and having a circular cross-section configuration is formed a tubular passage 2 for transporting powder 8 carried by gas, a desired polarity plasma electrode 3 is disposed on the axis of the tubular passage 2 on its outlet side, a high voltage is applied intermittently to this plasma electrode 3 by means of a voltage source 5 and a discharge gap 5b, and also there is provided an anti-object corona electrode 23 connected to the plasma electrode 3 and directed to the outlet side. In addition, as an opposite polarity plasma electrode 4, a corona discharge electrode having a relatively large radius of curvature at its tip end is disposed as shown in Fig. 15, and this plasma electrode 4 is grounded via a lead wire 21. It is to be noted that while the discharge gap 5b is disposed at two locations in the figure, in practice one of them is omitted. Also, reference numeral 5a designates a high frequency voltage source for feeding electric power to the D.C. voltage source 5.

In addition, an adhesion preventing gas indicated by an arrow 17 is used for the purpose of preventing the powder from adhering to the tip end of the desired polarity plasma electrode and the tip end of the anti-object corona electrode 23. Also, a pattern adjusting gas indicated by an arrow 30 is ejected in a turning flow from a pattern adjusting gas jet port 29 opening in the proximity of an end of the tubular passage 2 so that an ejecting pattern of the charged powder 9 blown from the electrostatic powder painting apparatus can be adjusted by regulating the flow rate of this gas. According to the illustrated embodiment, owing to the powder charging action according to the present invention which was already explained in detail, powder charged very strongly in the same polarity as the desired polarity plasma electrode in the region between the desired polarity plasma electrode 3 and the opposite polarity plasma electrode 4, is ejected, and furthermore, in addition thereto since the powder is again charged by an intense electric field and a corona discharge current established from the tip end of the anti-object corona electrode 23 towards the object, i.e. the article to be painted, the powder can practice electrostatic powder painting with extremely high painting efficiency and back painting property, owing to a strong electric field directed from the tip end of the electrostatic powder painting apparatus towards the article to be painted as well as a large amount of charge on the powder. It is to be noted that in the electrostatic powder painting system according to the above-described embodiment, the means for practicing the basic elements of the powder charging apparatus according to the present invention as described in detail above can be arbitrarily selected and combined depending upon the purpose, and also with regard to the methods for forming and adjusting the ejecting pattern, besides the illustrated means, every means known in the art can be employed. This is also true with respect to the embodiments shown in Figs. 13 and 14, respectively.

Fig. 16 shows yet another embodiment, in which an electrostatic powder painting apparatus having well matched penetrating performance and painting efficiency can be provided by making use of the powder charging apparatus according to the present invention. In Fig. 16, on the inside of a cylindrical body 1 made of insulating material and having a circular cross-section area, is formed a tubular passage for transporting powder 8 carried by gas, an anti-object corona electrode 23 opposed to an article 31 to be painted is provided on the axis of the tubular passage 2 on the outlet side thereof, a desired polarity plasma electrode 3 is disposed at the upstream of the corona electrode 23 a little apart therefrom, an output terminal 5d at

the highest voltage of a D.C. voltage source 5 is connected to the electrode 3 via a discharge gap 5b, an intermediate voltage terminal of the D.C. voltage source 5 is connected to the anti-object corona electrode 23, and an opposite polarity plasma electrode disposed at the most upstream position is grounded. In this preferred embodiment, charging of powder is effected in the region between the plasma electrode 4 and the plasma electrode 3 similarly to the previously described embodiments, and an appropriate intermediate voltage value is selected and applied to the electrode 23 so that the electrode 23 may establish such degree of somewhat weak electric field that it may not deteriorate a penetrating performance of the charged powder flow 9 but it may appropriately assist the flying of the powder towards the article to be painted. With the above-mentioned provision, an electrostatic powder painting apparatus having both a penetrating performance and a painting efficiency which are intermediate and well matched with each other, can be provided.

While the desired polarity plasma electrode and the opposite polarity plasma electrode used according to the present invention was explained in connection to a needle electrode and an A.C. driven plasma generating electrode in the above description, if necessary, other types of electrodes which can generate plasma such as a knife-edge electrode, a thin wire electrode, etc. could be employed.

Since the present invention has the above-described features, and since the pair of electrodes used for charging powder are both plasma generating electrodes such as needle electrodes, knife-edge electrodes, wire electrodes, A.C. drive type electrodes, etc., stable operation in powder for a long period of time can be assumed without adhesion and accumulation of powder to and on the respective electrodes, and for the purpose of charging of powder paint, strong long-time stable charging performance can be assured almost independently of material properties of the powder. Especially, according to the present invention, since a D.C. voltage is applied intermittently between the respective electrodes, as compared to the case where the same D.C. voltage is applied continuously, an amount of charge can be increased by 30 - 100 %.

In addition, by combining powder paint that has been internally strongly charged by the powder charging apparatus according to the present invention with an external electric field, an external ionic current and ejection pattern adjusting means, an electrostatic powder painting apparatus having extremely excellent penetrating performance, thick painting performance, painting efficiency and back painting performance, can be newly provided, and

all these apparatuses present high performance stability in a long term operation. The external electrical field and the external ionic current employed in the above-described electrostatic powder painting apparatus is very important even in the case where the external electric field and the external ionic current are not present at all, and it was considered almost impossible in the prior art to practice such electrostatic powder painting stably and at a high efficiency for a long term independently of material properties of powder paint.

Whereas in the prior art, as shown in Figs. 17 and 18, one of a pair of electrodes employed for charging powder is a corona discharge electrode 43, while the other is a cylindrical electrode 44 which can be deemed substantially to be a plane, and under an operating conditions, since there exist only a high voltage applied between the respective electrodes and a monopolar desired polarity ionic current flowing unidirectionally, essentially powder is apt to adhere to and accumulate on the surface of the cylindrical electrode 44, and even a little powder, once it has adhered to the electrode 44, it causes generation of back corona discharge, an opposite polarity ionic current flows inversely from this electrode 44 towards the corona discharge electrode 43, resulting in neutralization of the desired polarity ions and electric charge, thereby charging performance of the electrodes would be lowered quickly as the powder adheres and accumulates, and continuous operation for a long term would become difficult. This phenomenon is especially remarkable in the case of charging powder having a low melting point and strong adhesiveness, and it is practically impossible to realize practical stable operation for more than several hours even with counter-measures such as improvements in the material, shape and surface working of the cylindrical electrode 49 and in the flow rate and ejecting velocity of a clean air 58.

#### Claims

1. Powder charging apparatus comprising an insulative tubular passage (1), means for delivering to the tubular passage a conveying gas and the powder to be charged, a pair of plasma electrodes (3,4) for respectively generating plasma of required polarity and plasma of opposite polarity, means (5) for applying DC voltage to said plasma electrodes, said plasma electrodes being connected so that the field therebetween extends in said tubular passage and the apparatus being arranged so that the said powder flows in a dispersed state in said gas through an area of said field where mainly ions of required polarity exist, one (3) of said plasma electrodes (3,4) being a plasma electrode

- trode of required polarity and the other (4) being a plasma electrode of opposite polarity, characterised in that the location of the other (4) of the electrodes relative to the powder flow is such that it is substantially avoided that the powder in the dispersed state flows through the area of the field where mainly ions of said opposite polarity exist, and said DC voltage is intermittently applied via a gap (5b) which disperses ions well in said insulative tubular passage
2. A power charging apparatus as claimed in Claim 1, characterised in that the discharge gap (5b) provided between the higher voltage side plasma electrode and the D.C. voltage source is formed in the lead wire (5c) connecting said higher voltage side plasma electrode to the D.C. voltage source (5)
  3. A powder charging apparatus as claimed in Claim 1, characterised in that the discharge gap (5b) provided between the higher voltage side plasma electrode and the D.C. voltage source is disposed within a gas jet port (16a) of the higher voltage side plasma electrode.
  4. A powder charging apparatus as claimed in Claim 2 characterised in that the discharge gap (5b) is provided between the higher voltage side plasma electrode among said pair of plasma electrodes and the D.C. voltage source between said higher voltage plasma electrode and an end portion of a lead wire connected to the D.C. voltage source within a gas jet port (16a) of the higher voltage side plasma electrode.
  5. A powder charging apparatus as claimed in Claim 1 characterised in that a voltage-current characteristic of a desired polarity plasma electrode (3) from which desired polarity ions are drawn is made larger than a voltage-current characteristic of an opposite polarity plasma electrode (4) from which opposite polarity ions are drawn.
  6. A powder charging apparatus as claimed in Claim 1 characterised in that the space (13) where mainly desired polarity ions exist is upstream of the plasma electrode (3) generating said desired polarity ions with respect to the direction of transportation of the powder
  7. A powder charging apparatus as claimed in Claim 1 characterised in that the plasma electrodes are provided with means (17, 19) for preventing adhesion of powder thereto.
  8. A powder charging apparatus as claimed in Claim 1 characterised in that the desired polarity plasma electrode is connected to ground (20).
  9. An electrostatic powder painting apparatus comprising a powder charging apparatus including an insulative tubular passage (1), means for delivering to the tubular passage a conveying gas and the powder to be charged, a pair of plasma electrodes (3,4) for respectively generating plasma of required polarity and plasma of opposite polarity, means (5) for applying DC voltage to said plasma electrodes, said plasma electrodes being connected so that the field there between extends in said tubular passage and the apparatus being arranged so that the said powder flows in a dispersed state in said gas through an area of said field where mainly ions of required polarity exist, one (3) of said plasma electrodes (3,4) being a plasma electrode of required polarity and the other (4) being a plasma electrode of opposite polarity characterised in that the location of said other electrode (4) relative to the powder flow is such that it is substantially avoided that the powder in the dispersed state flows through the area of the field where mainly ions of said opposite polarity exist, and said DC voltage is intermittently applied via a gap (5b) which disperses ions well in said insulative tubular passage.
  10. An electrostatic powder painting apparatus as claimed in Claim 9, characterised in that the insulative tubular passage for transporting powder carried by gas is provided with a short tube (22) on its outlet side.
  11. An electrostatic powder painting apparatus as claimed in Claim 9 characterised in that the opposite polarity plasma electrode (4) is connected to ground, the desired polarity plasma electrode (3) is disposed in the proximity of the downstream end of the tubular passage and includes a corona discharge electrode (23) in said tubular passage facing outwardly in the direction of an object to be coated.
  12. A powder charging method including the steps of providing an insulative tubular passage (1), with one plasma electrode (3) on an axis therein for generating plasma of required polarity and another plasma electrode (4) therein for generating plasma of opposite polarity, delivering a conveying gas and powder to be charged to the passage, applying D.C. voltage to said electrodes to create a field there between ex-

tending in said tubular passage so that the powder flows in dispersed state through an area of said field where mainly ions of required polarity exist, characterised in that the location of said other electrode (4) relative to the powder flow is such that it is substantially avoided that the powder in the dispersed state flows through the area of the field where mainly ions of said opposite polarity exist, and in that said D.C. voltage is applied intermittently between said electrodes to generate plasma in said passage in the direction of said axis and the powder is transported in said passage in the direction of said axis

13. The method in Claim 12 including applying an A.C. voltage between said pair of electrodes
14. The method in Claim 13 including generating plasma in a manner that provides a space (13) where mainly desired polarity ions exist and a space (14) where mainly opposite polarity ions exist
15. A powder charging method including the steps of delivering a conveying gas and the powder to a tubular insulative passage (1) with a pair of plasma generating electrodes therein, for respectively generating plasma of required polarity and plasma of opposite polarity and applying D.C. voltage intermittently to said plasma electrodes which are so connected that the field therebetween extends in said tubular passage and so that the powder flows in said gas through an area of the field where mainly ions of required polarity exist, characterised in that the location of the electrode for generating plasma of opposite polarity relative to the powder flow is such that it is substantially avoided that the powder in the dispersed state flows through the area of the field where mainly ions of said opposite polarity exist, and in that said powder is caused to flow only through the area where the mainly desired polarity ions exist.
16. The method in claim 15 including transporting powder finely dispersed in a gas in said space where mainly desired polarity ions exist
17. The method in claim 15 including keeping powder remote from said space where mainly opposite polarity ions exist.

#### Patentansprüche

1. Pulveraufladevorrichtung, aufweisend :  
inen isolierten, rohrförmigen Durchgang (1);  
ine Einrichtung zum Ausgeben eines Träger-

gases und des aufzuladenden Pulvers an den rohrförmigen Durchgang, ein Paar von Plasma-Elektroden (3,4) zum Erzeugen von jeweils Plasma der erforderlichen Polarität und Plasma der entgegengesetzten Polarität, Hilfsmittel (5) zum Anlegen einer Gleichspannung an die Plasma-Elektroden, wobei die Plasma-Elektroden so verbunden sind, daß das dazwischliegende Feld sich in den rohrförmigen Durchgang erstreckt und die Vorrichtung so angeordnet ist, daß das Pulver in einem verteilten Zustand in dem Gas durch einen Bereich des Felds fließt, in dem Überwiegend Ionen der erforderlichen Polarität vorhanden sind, wobei eine (3) der Plasma-Elektroden (3,4) eine Plasma-Elektrode der erforderlichen Polarität ist und die andere (4) eine Plasma-Elektrode der entgegengesetzten Polarität ist, dadurch gekennzeichnet, daß die Anordnung der anderen (4) der Elektroden (3,4) relativ zum Pulverfluß so ist, daß es im wesentlichen vermieden ist, daß das Pulver im verteilten Zustand durch das Gebiet des Felds fließt, in dem Überwiegend Ionen der entgegengesetzten Polarität vorhanden sind, und daß die Gleichspannung intermittierend durch eine Öffnung (5b) angelegt ist, die Ionen in dem isolierten rohrförmigen Durchgang gut verteilt.

2. Pulveraufladevorrichtung wie in Anspruch 1 beansprucht, dadurch gekennzeichnet, daß die Ausgangsöffnung (5b), die zwischen der Plasma-Elektrode an der Seite der höheren Spannung und der Gleichspannungsquelle vorgesehen ist, in dem Zuführungsdraht (5c) ausgebildet ist, der die Plasma-Elektrode der Seite mit der höheren Spannung mit der Gleichspannungsquelle (5) verbindet.
3. Pulveraufladevorrichtung wie in Anspruch 1 beansprucht, dadurch gekennzeichnet, daß die Ausgangsöffnung (5b), die zwischen der Plasma-Elektrode an der Seite der höheren Spannung und der Gleichspannungsquelle vorgesehen ist, in einer Gasstromöffnung (16a) der Plasma-Elektrode der Seite mit der höheren Spannung angeordnet ist.
4. Pulveraufladevorrichtung wie in Anspruch 2 beansprucht, dadurch gekennzeichnet, daß die Ausgangsöffnung (5b) zwischen der Plasma-Elektrode des Paares von Plasma-Elektroden, die an der Seite der höheren Spannung ist, und der Gleichspannungsquelle vorgesehen ist, zwischen der Plasma-Elektrode mit der höheren Spannung und in dem Endteil des Zuführungsdrahts, der mit der Gleichspannungsquelle innerhalb einer Gasstromöffnung (16a)

der Plasma-Elektrode der Seite mit der höheren Spannung verbunden ist.

5. Pulveraufladevorrichtung wie in Anspruch 1 beansprucht, dadurch gekennzeichnet, daß eine Spannungs-Strom-Charakteristik einer Plasma-Elektrode (3) erforderlicher Polarität, von der Ionen erforderlicher Polarität angezogen werden, größer gemacht ist als eine Spannungs-Strom-Charakteristik einer Plasma-Elektrode (4) entgegengesetzter Polarität, von der Ionen entgegengesetzter Polarität angezogen werden.
6. Pulveraufladevorrichtung wie in Anspruch 1 beansprucht, dadurch gekennzeichnet, daß der Raum (13), in dem überwiegend Ionen erforderlicher Polarität vorhanden sind, bezüglich der Transportrichtung des Pulvers stromaufwärts von der Plasma-Elektrode (3) ist, die die Ionen erforderlicher Polarität erzeugt.
7. Pulveraufladevorrichtung wie in Anspruch 1 beansprucht, dadurch gekennzeichnet, daß die Plasma-Elektroden mit einer Einrichtung (17, 19) zum Verhindern von Adhäsion von Pulver auf ihnen versehen sind.
8. Pulveraufladevorrichtung wie in Anspruch 1 beansprucht, dadurch gekennzeichnet, daß die Plasma-Elektrode der gewünschten Polarität mit Erde (20) verbunden ist.
9. Elektrostatische Pulverauftragsvorrichtung, die eine Pulveraufladevorrichtung aufweist, die umfaßt:
  - einen isolierten, rohrförmigen Durchgang (1), eine Einrichtung zum Ausgeben eines Trägergases und des aufzuladenden Gases an den rohrförmigen Durchgang, ein Paar von Plasma-Elektroden (3,4) zum Erzeugen jeweils von Plasma der erforderlichen Polarität und Plasma der entgegengesetzten Polarität, Hilfsmittel (5) zum Anlegen einer Gleichspannung an die Plasma-Elektroden, wobei die Plasma-Elektroden so verbunden sind, daß das dazwischenliegende Feld sich in den rohrförmigen Durchgang erstreckt und die Vorrichtung so angeordnet ist, daß das Pulver in einem verteilten Zustand in dem Gas durch einen Bereich des Feldes fließt, in dem überwiegend Ionen der erforderlichen Polarität vorhanden sind, wobei eine (3) der Plasma-Elektroden (3,4) eine Plasma-Elektrode der erforderlichen Polarität ist und die andere (4) eine Plasma-Elektrode der entgegengesetzten Polarität ist, dadurch gekennzeichnet, daß die Anordnung der anderen Elektrode (4) relativ zum Pulverfluß so ist,

daß es im wesentlichen vermieden ist, daß das Pulver im verteilten Zustand durch das Gebiet des Feldes fließt, in dem überwiegend Ionen der entgegengesetzten Polarität vorhanden sind, und daß die Gleichspannung intermittierend durch eine Öffnung (5b) angelegt ist, die Ionen in dem isolierten rohrförmigen Durchgang gut verteilt.

10. Elektrostatische Pulverauftragsvorrichtung wie in Anspruch 9 beansprucht, dadurch gekennzeichnet, daß der isolierte rohrförmige Durchgang zum Transportieren von Pulver, das von Gas getragen wird, an seiner Austrittsseite mit einem kurzen Rohr (22) versehen ist.
11. Elektrostatische Pulverauftragsvorrichtung wie in Anspruch 9 beansprucht, dadurch gekennzeichnet, daß die Plasma-Elektrode (4) mit entgegengesetzter Polarität mit Erde verbunden ist, daß die Plasma-Elektrode (3) mit gewünschter Polarität in der Nähe des stromabwärts gelegenen Endes des rohrförmigen Durchgangs angeordnet ist und eine Korona-Entladungselektrode (23) in dem rohrförmigen Durchgang einschließt, die nach außen in die Richtung eines zu beschichtenden Gegenstands zeigt.
12. Verfahren zum Aufladen von Pulver, das die Schritte einschließt zum Vorsehen eines isolierten rohrförmigen Durchgangs (1), mit einer Plasma-Elektrode (3) auf einer Achse darin zum Erzeugen von Plasma gewünschter Polarität und einer anderen Plasma-Elektrode (4) darin zum Erzeugen von Plasma entgegengesetzter Polarität, zum Ausgeben eines Trägergases und aufzuladenden Pulvers an den Durchgang und zum Anlegen einer Gleichspannung an die Elektroden zum Erzeugen eines dazwischenliegenden Feldes, das sich in den rohrförmigen Durchgang erstreckt, so daß das Pulver in verteiltem Zustand durch einen Bereich des Feldes fließt, in dem überwiegend Ionen der gewünschten Polarität vorhanden sind, dadurch gekennzeichnet, daß die Anordnung der anderen Elektrode (4) relativ zum Pulverfluß derartig ist, daß es im wesentlichen vermieden wird, daß das Pulver im verteilten Zustand durch das Gebiet des Feldes fließt, in dem überwiegend Ionen der entgegengesetzten Polarität vorhanden sind, und daß die Gleichspannung intermittierend zwischen den Elektroden angelegt ist, um Plasma in dem Durchgang zu erzeugen in die Richtung der Achse, und das Pulver transportiert wird in dem Durchgang in die Richtung der Achse.

13. Verfahren wie in Anspruch 12, das weiterhin das Anlegen einer Wechselspannung zwischen dem Paar von Elektroden umfaßt.
14. Verfahren wie in Anspruch 13, das weiterhin das Erzeugen von Plasma in einer Art und Weise umfaßt, daß ein Raum (13), in dem überwiegend Ionen gewünschter Polarität vorhanden sind, und ein Raum (14), in dem überwiegend Ionen entgegengesetzter Polarität vorhanden sind, vorgesehen sind.
15. Verfahren zum Aufladen von Pulver, das die Schritte einschließt  
zum Ausgeben eines Trärgases und des Pulvers zu einem rohrförmigen isolierten Durchgang (1) mit einem Paar von plasmaerzeugenden Elektroden darin, zum Erzeugen jeweils von Plasma der gewünschten Polarität und Plasma der entgegengesetzten Polarität und zum Anlegen einer Gleichspannung intermittierend zu den Plasma-Elektroden, die so verbunden sind, daß das dazwischenliegende Feld sich in den rohrförmigen Durchgang erstreckt und so, daß das Pulver in dem Gas durch ein Gebiet des Felds fließt, in dem überwiegend Ionen der gewünschten Polarität vorhanden sind, dadurch gekennzeichnet, daß die Anordnung der Elektrode (1) zum Erzeugen von Plasma entgegengesetzter Polarität relativ zum Pulverfluß derartig ist, daß es im wesentlichen vermieden wird, daß das Pulver im verteilten Zustand durch das Gebiet des Felds fließt, in dem überwiegend Ionen der entgegengesetzten Polarität vorhanden sind, und daß das Pulver veranlaßt wird, nur durch das Gebiet zu fließen, in dem überwiegend Ionen gewünschter Polarität vorhanden sind.
16. Verfahren wie in Anspruch 15, das weiterhin den Transport von fein verteiltem Pulver in einem Gas in dem Raum einschließt, in dem überwiegend Ionen der gewünschten Polarität vorhanden sind.
17. Verfahren wie in Anspruch 15, das weiterhin das Fernhalten von Pulver von dem Raum einschließt, in dem überwiegend Ionen entgegengesetzter Polarität vorhanden sind.

#### Revendications

1. Dispositif de chargement de poudre comprenant un passage tubulaire isolant (1), un moyen pour alimenter le passage tubulaire en gaz de transport et en poudre à charger, deux électrodes à plasma (3, 4) pour produire respectivement du plasma de polarité requise et

du plasma de polarité opposée, un moyen (5) pour appliquer du courant continu auxdites électrodes à plasma, lesdites électrodes à plasma étant connectées de façon que le champ créé entre elles s'étende dans ledit passage tubulaire et le dispositif étant arrangé de façon que ladite poudre s'écoule à l'état dispersé dans ledit gaz en traversant une zone dudit champ où existent principalement des ions de polarité requise, l'une (3) desdites électrodes à plasma (3, 4) étant une électrode à plasma de polarité requise et l'autre (4) étant une électrode de polarité opposée, caractérisé en ce que l'emplacement de ladite autre électrode (4) par rapport à l'écoulement de poudre est tel qu'on évite pratiquement que la poudre à l'état dispersé traverse en s'écoulant la zone du champ où existent principalement des ions de ladite polarité opposée, et en ce que ladite tension continue est appliquée de façon intermittente en passant par un espace (5b) qui disperse bien les ions dans ledit passage tubulaire isolant.

2. Dispositif de chargement de poudre selon la revendication 1, caractérisé en ce que l'espace de décharge (5b), prévu entre l'électrode à plasma placée du côté de plus haute tension et la source de tension continue, est formé dans le conducteur (5c) qui relie ladite électrode à plasma placée du côté de plus haute tension à la source de tension continue (5).
3. Dispositif de chargement de poudre selon la revendication 1, caractérisé en ce que l'espace de décharge (5b) prévu entre l'électrode à plasma placée du côté de plus haute tension et la source de tension continue est disposé à l'intérieur d'un orifice de jet de gaz (16a) de l'électrode à plasma placée du côté de plus haute tension.
4. Dispositif de chargement de poudre selon la revendication 2, caractérisé en ce que l'espace de décharge (5b) est prévu entre l'électrode à plasma placée du côté de plus haute tension, faisant partie desdites deux électrodes à plasma, et la source de tension continue, entre ladite électrode à plasma à plus haute tension et une partie d'extrémité d'un conducteur reliée à la source de tension continue à l'intérieur d'un orifice de jet de gaz (16a) de l'électrode à plasma placée du côté de plus haute tension.
5. Dispositif de chargement de poudre selon la revendication 1, caractérisé en ce qu'on rend une caractéristique tension/courant d'une élec-

- trode à plasma (3) de polarité désirée, de laquelle on obtient des ions de polarité désirée, plus grande qu'une caractéristique tension/courant d'une électrode à plasma (4) de laquelle sont obtenus des ions de polarité opposée.
6. Dispositif de chargement de poudre selon la revendication 1, caractérisé en ce que l'espace (13) où existent principalement des ions de polarité désirée est situé en amont de l'électrode à plasma (3), produisant lesdits ions de polarité désirée, par rapport à la direction de transport de la poudre. 5
  7. Dispositif de chargement de poudre selon la revendication 1, caractérisé en ce que les électrodes à plasma comportent des moyens (17, 19) pour empêcher que la poudre y adhère. 10
  8. Dispositif de chargement de poudre selon la revendication 1, caractérisé en ce que l'électrode à plasma de polarité désirée est reliée à la terre (20). 15
  9. Appareil de peinture à poudre électrostatique, comprenant un dispositif de chargement de poudre qui comporte un passage tubulaire isolant (1), un moyen pour alimenter le passage tubulaire en gaz de transport et en poudre à charger, deux électrodes à plasma (3, 4) pour produire respectivement du plasma de polarité requise et du plasma de polarité opposée, un moyen (5) pour appliquer du courant continu auxdites électrodes à plasma, lesdites électrodes à plasma étant connectées de façon que le champ créé entre elles s'étende dans ledit passage tubulaire et le dispositif étant arrangé de façon que ladite poudre s'écoule à l'état dispersé dans ledit gaz en traversant une zone dudit champ où existent principalement des ions de polarité requise, l'une (3) desdites électrodes à plasma (3, 4) étant une électrode à plasma de polarité requise et l'autre (4) étant une électrode de polarité opposée, caractérisé en ce que l'emplacement de ladite autre électrode (4) par rapport à l'écoulement de poudre est tel qu'on évite pratiquement que la poudre à l'état dispersé traverse en s'écoulant la zone du champ où existent principalement des ions de polarité opposée, et en ce que ladite tension continue est appliquée de façon intermittente en passant par un espace (5b) qui disperse bien les ions dans ledit passage tubulaire isolant. 20 25 30 35 40 45 50 55
  10. Appareil de peinture à poudre électrostatique selon la revendication 9, caractérisé en ce que le passage tubulaire isolant pour le transport de la poudre portée par gaz est équipé, du côté de sa sortie, d'un court tube (22).
  11. Appareil de peinture à poudre électrostatique selon la revendication 9, caractérisé en ce que l'électrode à plasma (4) de polarité opposée est reliée à la terre, l'électrode à plasma (3) de polarité désirée étant disposée à proximité de l'extrémité aval du passage tubulaire et comprenant dans ledit passage tubulaire une électrode à décharge de couronne (23) qui regarde extérieurement dans la direction d'un objet à revêtir.
  12. Procédé de chargement de poudre qui comprend les opérations consistant à pourvoir intérieurement un passage tubulaire isolant (1) d'une électrode à plasma (3), selon un axe, pour fournir du plasma de polarité requise et d'une autre électrode à plasma (4) pour fournir du plasma de polarité opposée, à alimenter le passage en gaz de transport et en poudre à charger, à appliquer une tension continue aux dites électrodes afin de créer entre elles un champ qui s'étend dans ledit passage tubulaire de façon que la poudre s'écoule à l'état dispersé en traversant une zone dudit champ où existent principalement des ions de polarité requise, caractérisé en ce que l'emplacement de ladite autre électrode (4) par rapport à l'écoulement de poudre est telle qu'on évite pratiquement que la poudre à l'état dispersé traverse en s'écoulant la zone du champ où existent principalement des ions de ladite polarité opposée, et en ce qu'on applique ladite tension continue de façon intermittente entre lesdites électrodes pour produire dans le passage un plasma dans la direction dudit axe, la poudre étant transportée à l'intérieur dudit passage dans la direction dudit axe.
  13. Procédé selon la revendication 12, qui comprend l'application d'une tension alternative entre lesdites deux électrodes.
  14. Procédé selon la revendication 13, qui comprend la production de plasma d'une façon à procurer un espace (13) où existent principalement des ions de polarité désirée et un espace (14) où existent principalement des ions de polarité opposée.
  15. Procédé de chargement de poudre qui comprend les opérations consistant à alimenter en gaz de transport et en poudre un passage



tubulaire isolant (1) présentant intérieurement deux électrodes de production de plasma, pour produire respectivement du plasma de polarité requise et du plasma de polarité opposée, et à appliquer de façon intermittente une tension continue aux dites électrodes à plasma qui sont connectées de façon que le champ créé entre elles s'étende dans ledit passage tubulaire et de façon que la poudre s'écoule dans ledit gaz en traversant une zone du champ où existent principalement des ions de polarité requise, caractérisé en ce que l'emplacement de l'électrode produisant du plasma de polarité opposée par rapport à l'écoulement de poudre est telle qu'on évite pratiquement que la poudre à l'état dispersé traverse en s'écoulant la zone du champ où existent principalement des ions de ladite polarité opposée, et en ce que ladite poudre est forcée de s'écouler en traversant seulement la zone où existent les ions qui sont principalement de polarité désirée.

16. Procédé selon la revendication 15, qui comprend le transport, dans un gaz, d'une poudre finement dispersée à l'intérieur dudit espace où existent principalement des ions de polarité désirée.
17. Procédé selon la revendication 15, qui comprend le maintien de la poudre loin dudit espace où existent principalement des ions de polarité opposée.

FIG. 1

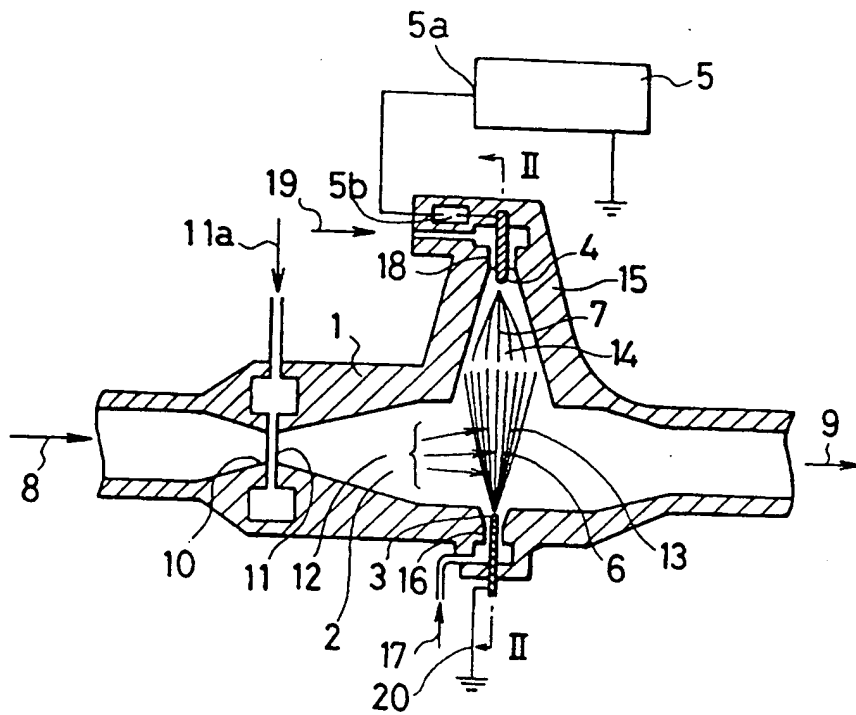


FIG. 2

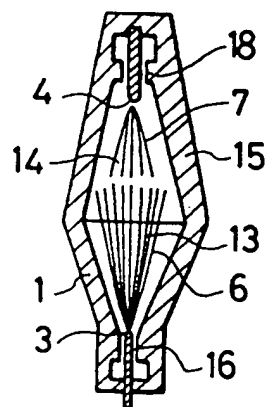


FIG. 3

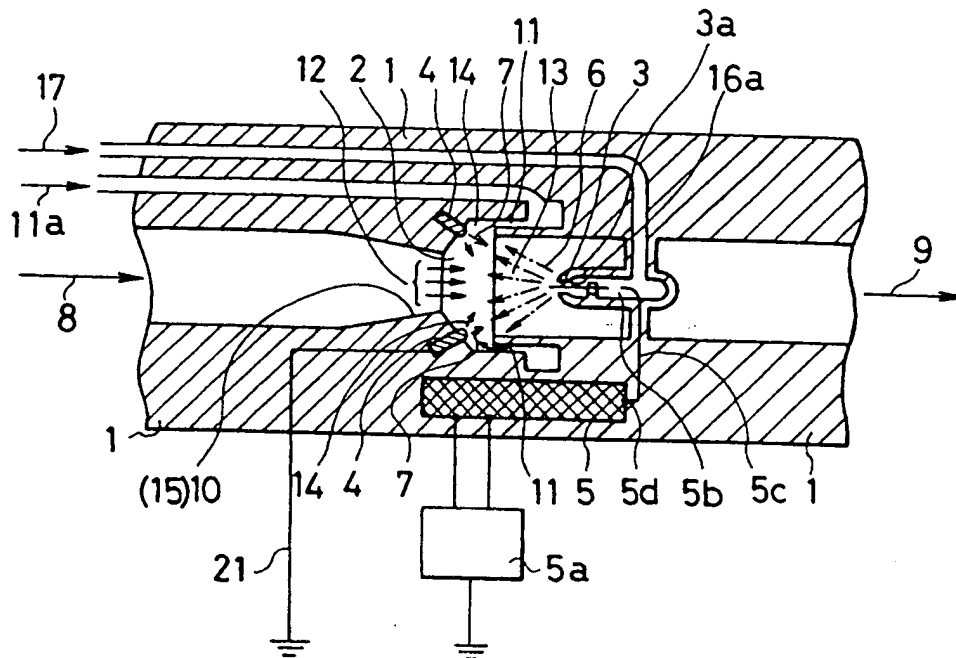


FIG. 4

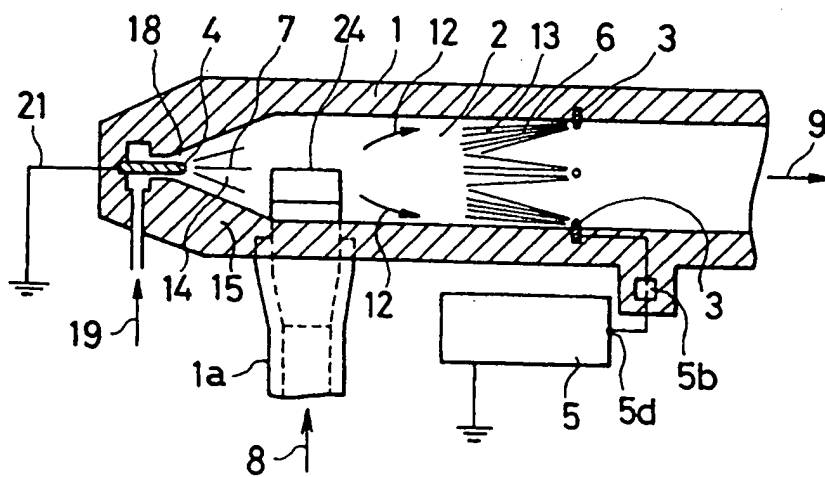


FIG. 5

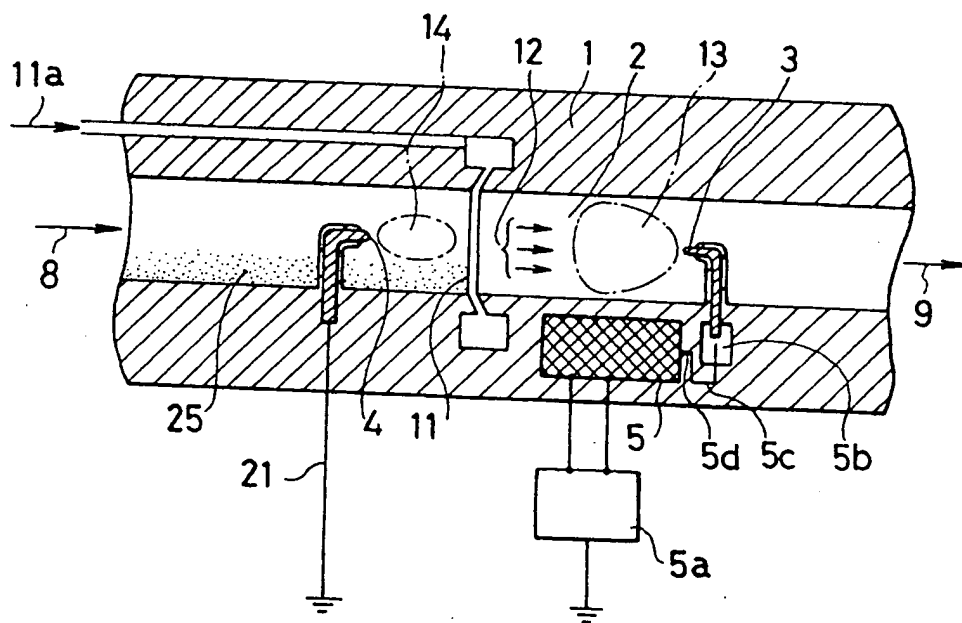


FIG. 6

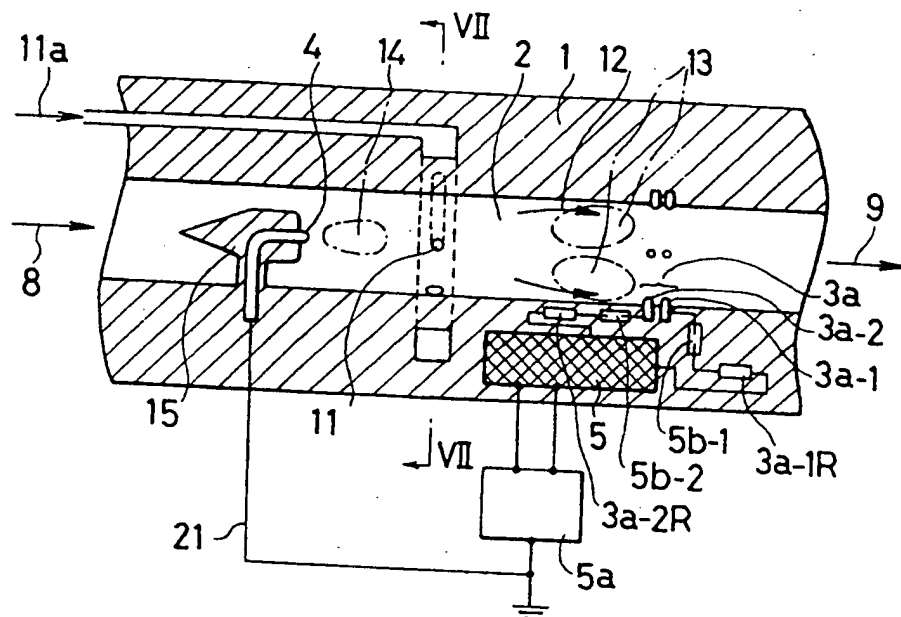


FIG. 7

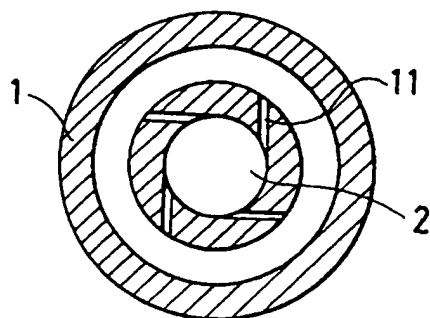


FIG. 8

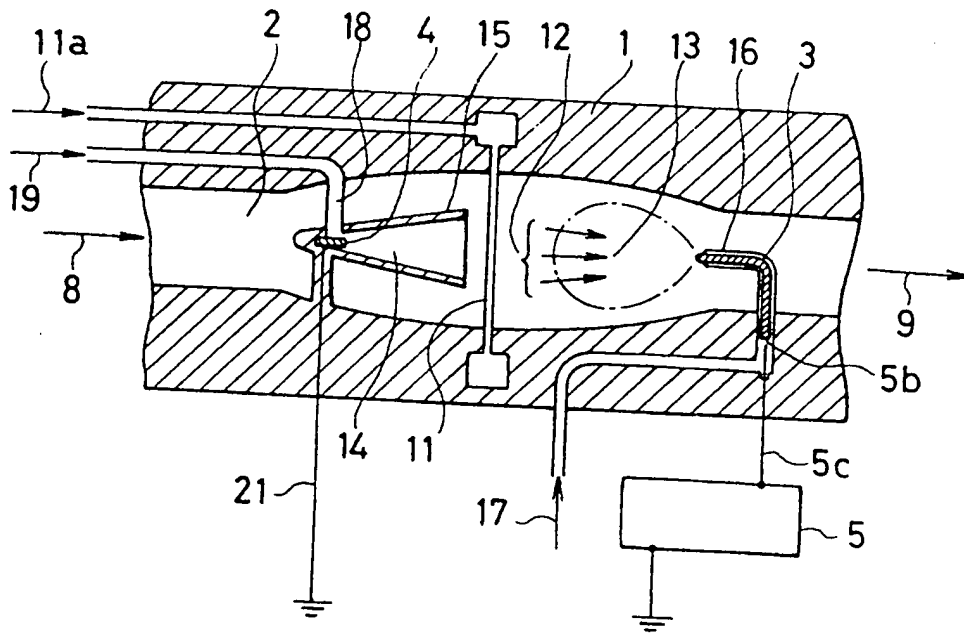


FIG. 9

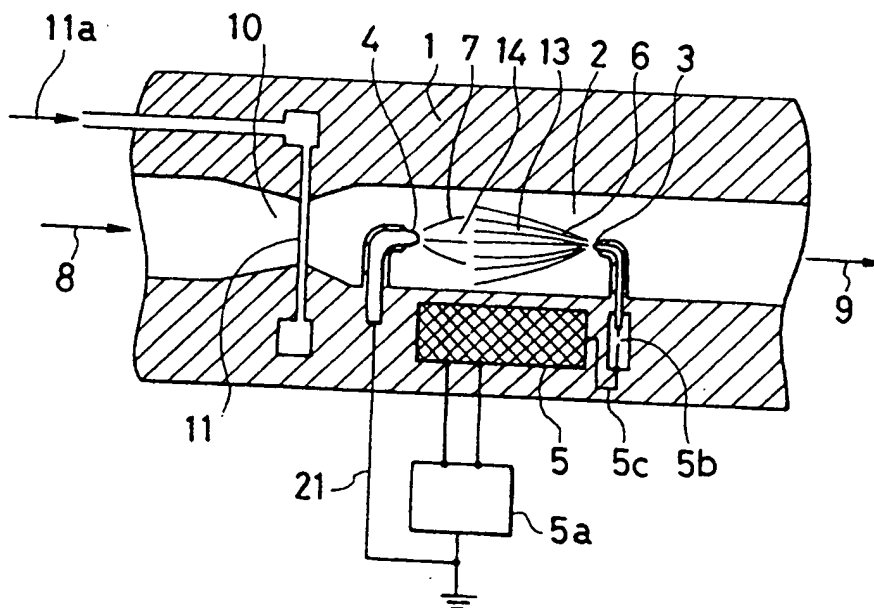


FIG. 10

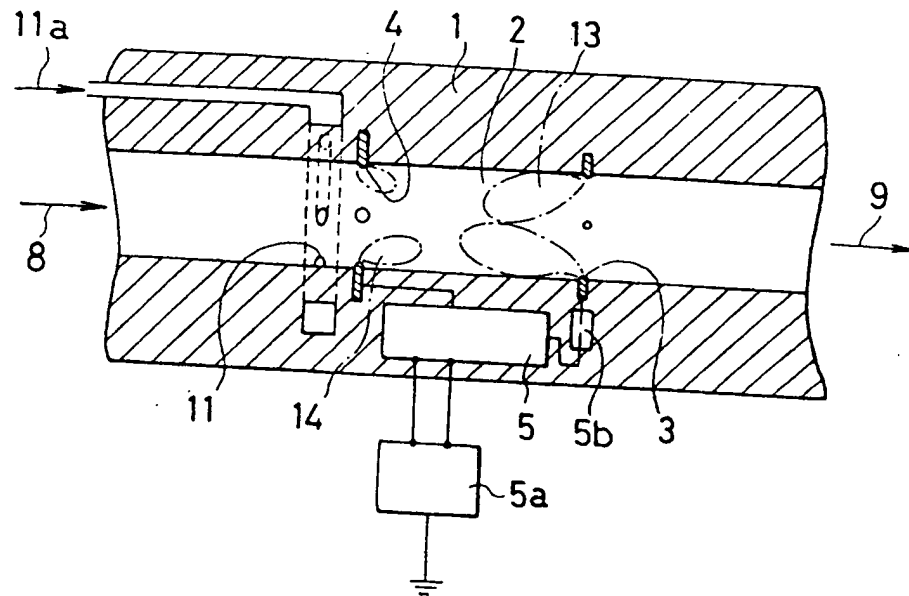


FIG. 11

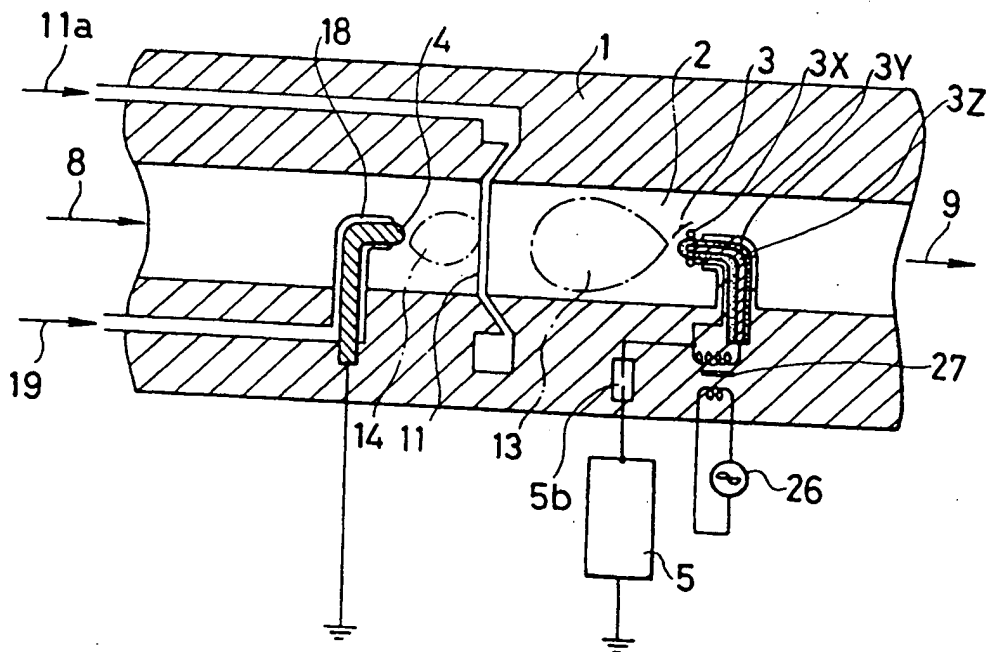


FIG.12

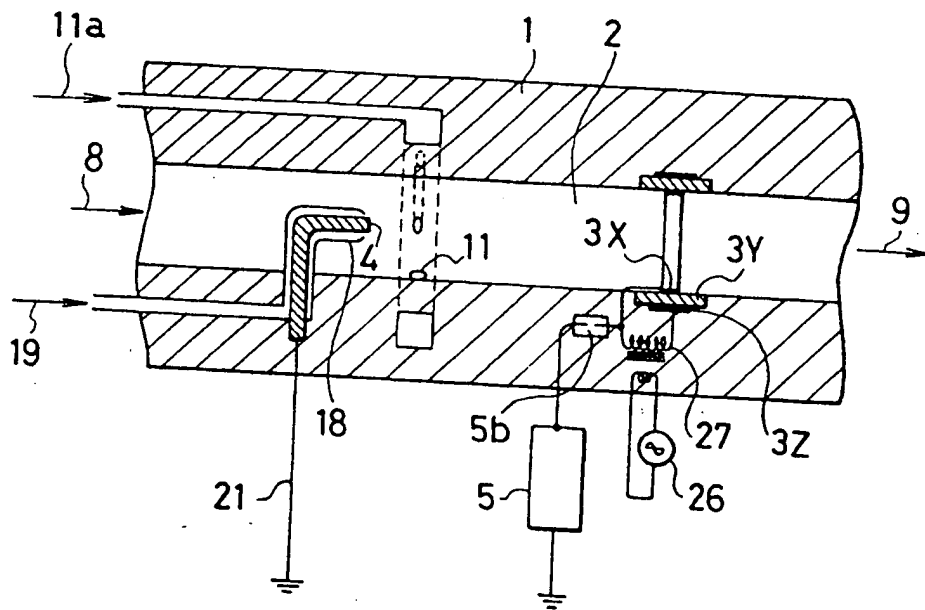




FIG. 13

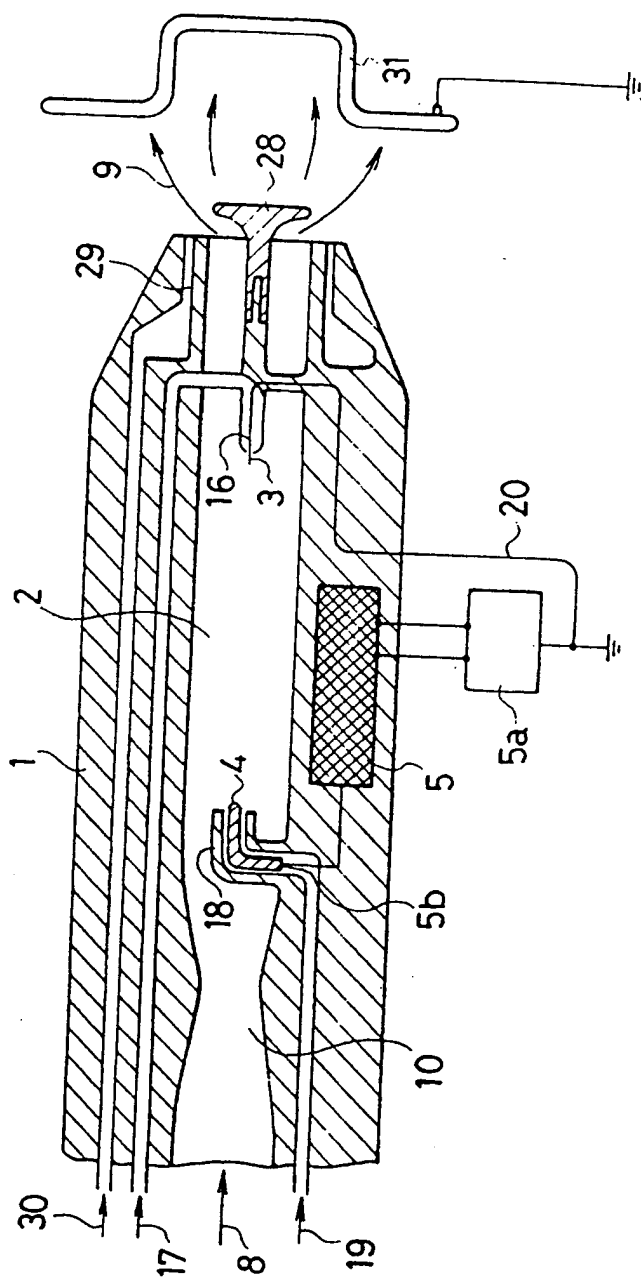


FIG. 14

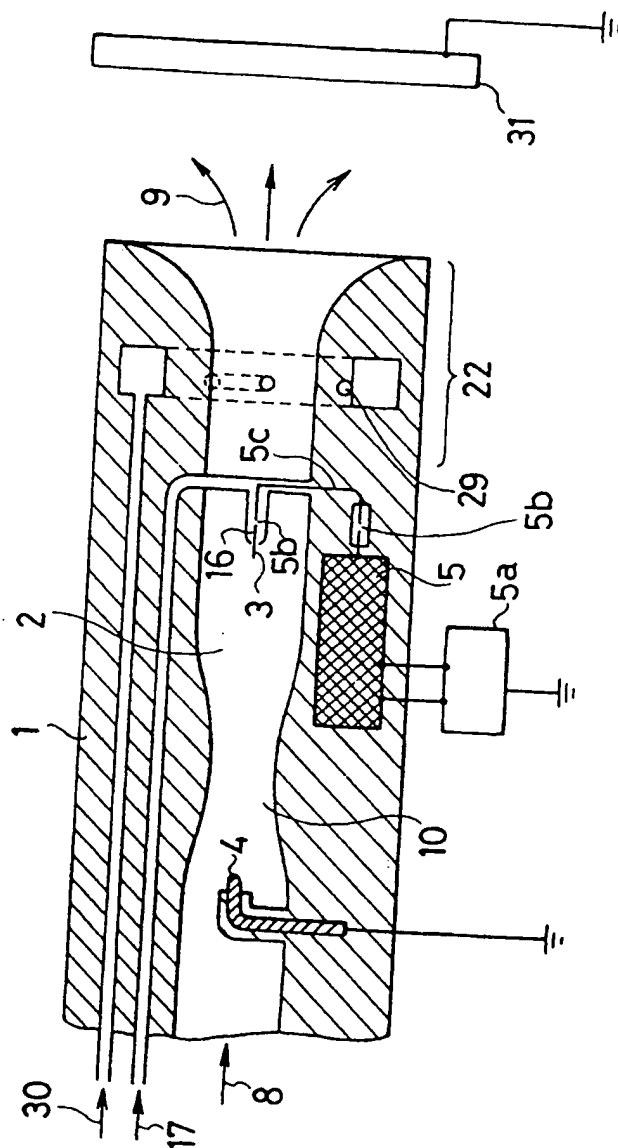


FIG. 15

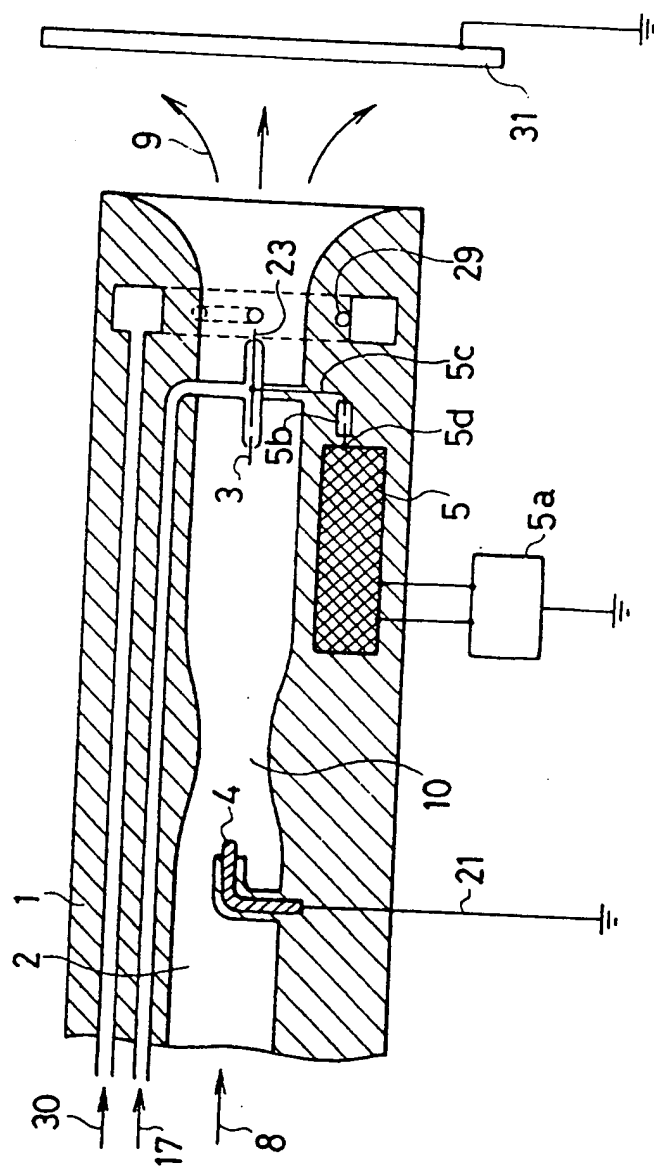


FIG. 16

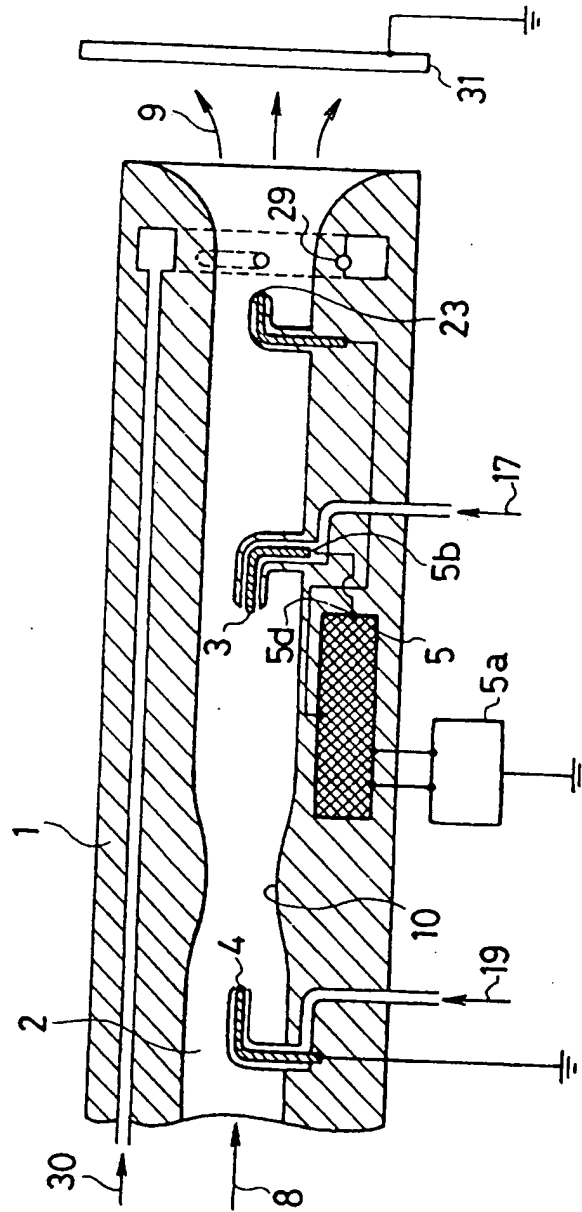


FIG. 17

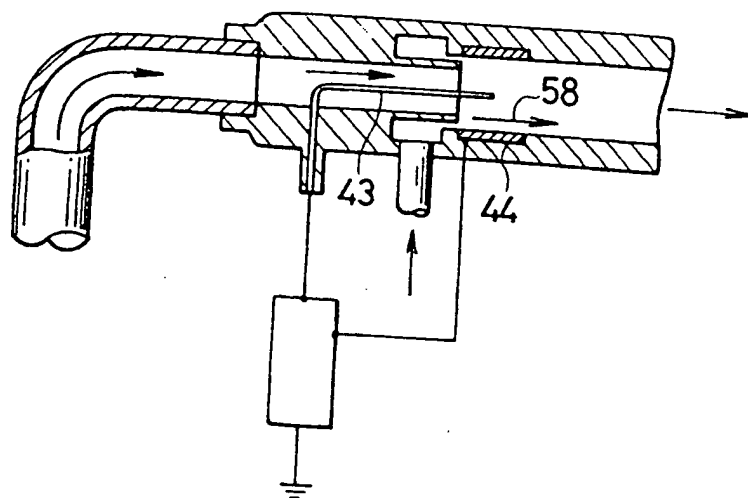


FIG. 18

